Question 3

3. Answer the following questions that relate to the analysis of chemical compounds.

(a) A compound containing the elements C, H, N, and O is analyzed. When a 1.2359 g sample is burned in excess oxygen, 2.241 g of $CO_2(g)$ is formed. The combustion analysis also showed that the sample contained 0.0648 g of H.

(i) Determine the mass, in grams, of C in the 1.2359 g sample of the compound.

$2.241 \text{ g } CO_2(g) \times \frac{1 \text{ mol } CO_2}{44.01 \text{ g } CO_2} \times \frac{1 \text{ mol C}}{1 \text{ mol } CO_2} \times \frac{12.011 \text{ g C}}{1 \text{ mol C}}$ $= 0.6116 \text{ g C}$	One point is earned for the correct answer.

(ii) When the compound is analyzed for N content only, the mass percent of N is found to be 28.84 percent. Determine the mass, in grams, of N in the original 1.2359 g sample of the compound.

$1.2359 \text{ g sample} \times 0.2884 = 0.3564 \text{ g N}$	One point is earned for the correct answer.

(iii) Determine the mass, in grams, of O in the original 1.2359 g sample of the compound.

Because the compound contains only C, H, N, and O, mass of O = g sample − (g H + g C + g N) $= 1.2359 - (0.0648 + 0.6116 + 0.3564) = 0.2031 \text{ g}$	One point is earned for the answer consistent with the answers in parts (a)(i) and (a)(ii).

(iv) Determine the empirical formula of the compound.

Converting all masses to moles, $0.6116 \text{ g C} \times \frac{1 \text{ mol C}}{12.011 \text{ g C}} = 0.05092 \text{ mol C}$ $0.0648 \text{ g H} \times \frac{1 \text{ mol H}}{1.0079 \text{ g H}} = 0.06429 \text{ mol H}$ $0.3564 \text{ g N} \times \frac{1 \text{ mol N}}{14.007 \text{ g N}} = 0.02544 \text{ mol N}$ $0.2031 \text{ g O} \times \frac{1 \text{ mol O}}{16.00 \text{ g O}} = 0.01269 \text{ mol O}$	One point is earned for all masses converted to moles. Note: Moles of C may be shown in part (a)(i).

Divide all mole quantities by the smallest number of moles: 0.05092 mol ÷ 0.01269 mol = 4.013 0.06429 mol ÷ 0.01269 mol = 5.066 0.02544 mol ÷ 0.01269 mol = 2.005 0.01269 mol ÷ 0.01269 mol = 1.000 ⇒ Empirical formula is $C_4H_5N_2O$	One point is earned for dividing by the smallest number of moles. One point is earned for the empirical formula consistent with the ratio of moles calculated.

(b) A different compound, which has the empirical formula CH_2Br, has a vapor density of 6.00 g L^{-1} at 375 K and 0.983 atm. Using these data, determine the following.

(i) The molar mass of the compound

$PV = nRT \Rightarrow \frac{PV}{RT} = n$ $\frac{(0.983\text{ atm})(1.00\text{ L})}{(0.0821\text{ L atm mol}^{-1}\text{K}^{-1})(375\text{ K})} = 0.0319\text{ mol}$ molar mass of gas ($\boldsymbol{M}$) = $\frac{6.00\text{ g}}{0.0319\text{ mol}} = 188\text{ g mol}^{-1}$ *OR* $\boldsymbol{M} = \frac{DRT}{P} = \frac{6.00\text{ g L}^{-1} \times 0.0821\text{ L atm mol}^{-1}\text{ K}^{-1} \times 375\text{ K}}{0.983\text{ atm}}$ $= 188\text{ g mol}^{-1}$	One point is earned for applying the gas law to calculate *n*. One point is earned for calculating the molar mass. *OR* Two points are earned for calculating the molar mass using $\boldsymbol{M} = \frac{DRT}{P}$

(ii) The molecular formula of the compound

Each CH_2Br unit has mass of 12.011 + 2(1.0079) + 79.90 = 93.9 g, and $\frac{188\text{ g}}{93.9\text{ g}} = 2.00$, so there must be two CH_2Br units per molecule. Therefore, the molecular formula of the compound is $C_2H_4Br_2$.	One point is earned for the molecular formula that is consistent with the molar mass calculated in part (b)(i).

3. Answer the following questions that relate to the analysis of chemical compounds.

3A,

(a) A compound containing the elements C, H, N, and O is analyzed. When a 1.2359 g sample is burned in excess oxygen, 2.241 g of $CO_2(g)$ is formed. The combustion analysis also showed that the sample contained 0.0648 g of H.

(i) Determine the mass, in grams, of C in the 1.2359 g sample of the compound.

(ii) When the compound is analyzed for N content only, the mass percent of N is found to be 28.84 percent. Determine the mass, in grams, of N in the original 1.2359 g sample of the compound.

(iii) Determine the mass, in grams, of O in the original 1.2359 g sample of the compound.

(iv) Determine the empirical formula of the compound.

(b) A different compound, which has the empirical formula CH_2Br, has a vapor density of 6.00 g L^{-1} at 375 K and 0.983 atm. Using these data, determine the following.

(i) The molar mass of the compound

(ii) The molecular formula of the compound

3. a.) i.) $2.241\text{ g } CO_2 \times \frac{1\text{ mol } CO_2}{44.011} \times \frac{1\text{ mol C}}{1\text{ mol } CO_2} \times \frac{12.011\text{ g C}}{1\text{ mol C}}$ $\boxed{0.6116\text{ g C}}$

ii.) $1.2359\text{ g} \times \frac{28.84\text{ g}}{100\text{ g}}$ $\boxed{.3564\text{ g N}}$

iii.) .6116 g C
.3564 g N
.0648 g H
1.0328 g C,H,N

$1.2359 - 1.0328$ = $\boxed{.2031\text{ g O}}$

iv.) $.6116\text{ g C} \times \frac{1\text{ mol C}}{12.011\text{ g C}}$ .05092 mol C ÷ .01269 = 4.0

$.0646\text{ g H} \times \frac{1\text{ mol H}}{1.0079\text{ g H}}$ .06429 mol H ÷ .01269 = 5.0

$.3564\text{ g N} \times \frac{1\text{ mol N}}{14.007\text{ g N}}$ .02544 mol N ÷ .01269 = 2.00

$.2031\text{ g O} \times \frac{1\text{ mol}}{16.00\text{ g O}}$ .01269 mol O ÷ .01269 = 1.0

empirical formula = $\boxed{C_4H_5N_2O}$

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3A 2

b.) i.) $PM = DRT$

$M = \frac{DRT}{P} = \frac{(6.00\,g \cdot L^{-1})(.0821\,\frac{L\,atm}{mol\,K})(375\,K)}{(0.983\,atm)}$

$\boxed{M = 187.9\ g/mol}$

ii.) $\frac{\text{actual}}{\text{theoretical}} \times$ empirical formula $= \frac{187.9\,g/mol}{93.93\,g/mol} \times CH_2Br$

$= 2 \times CH_2Br$

molecular formula $= \boxed{C_2H_4Br_2}$

STOP

If you finish before time is called, you may check your work on this part only.
Do not turn to the other part of the test until you are told to do so.

3B₁

3. Answer the following questions that relate to the analysis of chemical compounds.

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(i) Determine the mass, in grams, of C in the 1.2359 g sample of the compound.

(ii) When the compound is analyzed for N content only, the mass percent of N is found to be 28.84 percent. Determine the mass, in grams, of N in the original 1.2359 g sample of the compound.

(iii) Determine the mass, in grams, of O in the original 1.2359 g sample of the compound.

(iv) Determine the empirical formula of the compound.

(b) A different compound, which has the empirical formula CH_2Br, has a vapor density of 6.00 g L^{-1} at 375 K and 0.983 atm. Using these data, determine the following.

(i) The molar mass of the compound

(ii) The molecular formula of the compound

a. i molar mass of $CO_2 = 44$ g/mol

moles of CO_2 formed $= \frac{2.241 g}{44 g/mol} = 0.051$ mol

Because CO_2 is the only carbon compound formed by complete combustion, the number of moles of CO_2 formed is equal to the number of moles carbon in the sample.

$0.051 mol \cdot 12 \frac{g}{mol} = 0.61 g$

$\boxed{0.61 g}$

ii. $28.84\% \cdot 1.2359 g = 0.3564 g$

$\boxed{0.3564 g}$

iii. Since there is only C, H, N, and O in the sample, and the masses of the first 3 are already known, it is simple to find the mass of O.

$1.2359 g - 0.61 g - 0.3564 g - 0.0648 g = 0.2047 g$

$\boxed{0.2047 g}$

GO ON TO THE NEXT PAGE.

3B2

iv. $\frac{0.61 g}{12 \frac{g}{mol}} = 0.51$ mol of C

$\frac{0.3564 g}{14 \frac{g}{mol}} = 0.25$ mol of N

$\frac{0.0648 g}{1 \frac{g}{mol}} = 0.0648$ mol of H

$\frac{0.2047 g}{16 \frac{g}{mol}} = 0.013$ mol of O ← smallest # of moles

$\frac{0.51 mol}{0.013 mol} \approx 39$ ← coefficient of C

$\frac{0.25 mol}{0.013 mol} \approx 19$ ← coefficient of N

$\frac{0.0648 mol}{0.013 mol} \approx 5$ ← coefficient of H

$\frac{0.013 mol}{0.013 mol} \approx 1$ ← coefficient of O

$\boxed{C_{39}N_{19}H_5O}$

b. i. $\frac{n}{V} = \frac{P}{RT}$ $\frac{n}{V} = \frac{0.983}{0.0821 \cdot 375} = 0.0319$

vapor density $= m_{molar} \cdot \frac{n}{V} = m_{molar} \cdot 0.0319 = 6.00$

$\boxed{m_{molar} = 188 \text{ g/mol}}$

ii. mass of empirical formula $= 12$ g/mol $+ 2$ g/mol $+ 80$ g/mol $= 94$ g/mol

$\frac{188 \text{ g/mol}}{94 \text{ g/mol}} = 2$ ← number coefficients of empirical formula must be multiplied by.

$\boxed{C_2H_4Br_2}$

STOP

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3C1

3. Answer the following questions that relate to the analysis of chemical compounds.

(a) A compound containing the elements C, H, N, and O is analyzed. When a 1.2359 g sample is burned in excess oxygen, 2.241 g of $CO_2(g)$ is formed. The combustion analysis also showed that the sample contained 0.0648 g of H.

(i) Determine the mass, in grams, of C in the 1.2359 g sample of the compound.

(ii) When the compound is analyzed for N content only, the mass percent of N is found to be 28.84 percent. Determine the mass, in grams, of N in the original 1.2359 g sample of the compound.

(iii) Determine the mass, in grams, of O in the original 1.2359 g sample of the compound.

(iv) Determine the empirical formula of the compound.

(b) A different compound, which has the empirical formula CH_2Br, has a vapor density of 6.00 g L^{-1} at 375 K and 0.983 atm. Using these data, determine the following.

(i) The molar mass of the compound

(ii) The molecular formula of the compound

a · 1.2359 g sample : contains $\boxed{.0648 g}$ H $\times \frac{1 mol}{1.008 g} = .0643$ mol H

$2.241 g\ CO_2 \times \frac{1 mol}{44.011 g} = .0509$ mol CO_2

I. .0509 mol CO_2

.0509 mol C, .1018 mol O_2

.0509 mol C $\times \frac{12.011 g}{1 mol} = \boxed{.6114 g\ C}$ in sample

II. 28.84% N

$.2884 \times 1.2359 = \boxed{.3564 g\ N}$ in sample

III. .0648 g H
.6114 g C
+ .3564 g N
1.0326 g

1.2359 g sample
− 1.0326 g
.2033 g O

IV. .0648 g H $\times \frac{1 mol}{1.0079 g} = .0643$ mol H / .0127 = 5

.6114 g C $\times \frac{1 mol}{12.011 g} = .0509$ mol C / .0127 = 4

.3564 g N $\times \frac{1 mol}{14.007 g} = .0254$ mol N / .0127 = 2

.2033 g O $\times \frac{1 mol}{16.00 g} = .0127$ mol O / .0127 = 1

$H_5C_4N_2O$ empirical formula.

GO ON TO THE NEXT PAGE.

 3C2

(b) CH_2Br 6.00g/L 375 K , .983 atm
↑
gaseous

$\frac{6.00g}{1.0L} \times \frac{1 mol}{93.9268g} = \boxed{\frac{.0639 mol}{L}}$

= .0639 M

L .0639 mol CH_2Br → 4 atoms

25% C .0639 mol C
50% H_2 .1278 mol H_2
25% Br .0639 mol Br

1/2

$.0639 mol C \times \frac{12.011g}{1mol} = .7675 g C$

$.1278 mol H_2 \times \frac{2.02g}{1 mol} = .2582 g H_2$

$.0639 mol Br \times \frac{79.90g}{1mol} = 5.106 g Br$

.2556 mol CH_2Br

STOP

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Question 3

Overview

Students were asked to use different types of data to determine the empirical formula of a compound. With a different set of data, students were asked to determine a molecular formula.

Sample: 3A
Score: 9

This response is clear, organized, and earned all 9 points: 1 point for part (a)(i), 1 point for part (a)(ii), 1 point for part (a)(iii), 3 points for part (a)(iv), 2 points for part (b)(i), and 1 point for part (b)(ii).

Sample: 3B
Score: 7

The point was not earned in part (a)(i) because the number of significant figures in the answer is off by more than one. Only 3 out of 4 points were earned in part (a)(iv) because the numbers are inappropriately rounded to such a degree that the empirical formula is not valid.

Sample: 3C
Score: 6

No points were earned in part (b) because the number of moles and molar mass are not calculated correctly.